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Is time money? The effects of seasonal time changes on European stock returns

Bachelor's Thesis

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Abstract

This thesis examines the effect of seasonal time changes on European stock returns. The results suggest that there is no seasonal time change effect in the European countries. The thesis contributes to the limited existing literature, as there is an ongoing debate on the existence of the time change effect, and there are no previous studies focusing on Europe. I base my analysis on a mean and multiple regression analysis as my main methods, complemented by cumulative distribution function plots. Further robustness checks comprise excluding outliers and a GARCH model. The data consists of 28 European total market indices with varying time spans.

Keywords Time change effect, Daylight saving anomaly, Market anomalies, Behavioral finance

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1. Introduction

In this thesis, I examine the relationship between seasonal time changes and European stock returns. I study whether the time changes have an adverse effect on the following Monday's returns, as many studies have shown that there exists a negative relationship between seasonal time changes and stock returns (see e.g. Kamstra, et al., 2000; Dowling & Lucey, 2005; Berument & Dogan, 2011). Sleep patterns have an important role in the topic: Kamstra et al. (2000) suggest that the so-called time change effect could be due to a minor sleep disturbance that a time change causes. They argue that a disturbance in sleeping rhythm causes anxiety in investors, lowers their risk tolerance in the following trading day and thus causes stock prices to descend.

The thesis is motivated by an ongoing debate on whether the time change effect exists. As the literature is limited and there is no consensus on the topic, it needs further examination. In addition, the geographical focus of the existing studies has not been on the European stock market, where the topic is timely due to the European Union's ongoing process on stopping the time changes.

As my main methods, I use mean and multiple regression analyses, complemented by cumulative distribution function plots. I test the robustness of my results by removing outliers and following a standard GARCH process. The data consists of 28 European total market indices with varying time spans, the earliest one starting in January 1965 and all the time series ending in December 2019.

The main results of my thesis conclude that there exists no time change effect in the 28 European countries that I examine. However, a few countries, such as Croatia, Estonia, Hungary, the Netherlands, Romania, and the UK, show the effect to some extent but those results do not endure the robustness tests. My results are supported by the majority of the existing literature.

2. Background and literature review

2.1. Seasonal time changes

Almost 70 countries in the world utilize seasonal time changes: They change the clocks one hour forward every spring, and one hour backward every fall. The rationale for turning the clocks lies in claims that increased time in daylight saves energy and makes for better free time after work. Events, such as the two World Wars and the energy crisis in the 1970's, made more countries change their clocks. Time changes are more common near the poles of the Earth, where the amount of natural light varies significantly. In contrast, near the Equator fewer countries utilize the seasonal time changes as sunlight is more consistent year-round.

Historically in Europe, each country has been able to decide freely on its time change policy. Thus, the time change dates have varied vastly compared to for example the US, where time changes have occurred in a more cohesive way. In 2001, the European Union started to implement synchronized time changes. Currently the Union is in the process of stopping the clock turning. The stop would take effect in 2021, and the member countries can individually decide on whether to stay in standard time or in summer time.

In this thesis, I use the term *seasonal time change*, or *time change* for short, and differentiate the changes based on the season they occur in: The time change from standard/"winter time" to summer time occurring in the spring is termed *spring time change*, and the time change from summer time to standard/"winter time" occurring in the fall is termed *fall time change*. In spring time change, one hour is lost and in fall time change one hour is gained. In the US, *daylight saving time* (DST) is a more commonly used term in describing summer time.

2.2. Minor sleep disturbances

As Kamstra et al. (2000) suggest, sleep disturbances have an important role in examining the time change effect. Even minor disturbances in sleep rhythm have an effect on our sleep duration and quality (see e.g. Lahti, et al., 2006; Lahti, et al., 2008). According to Kamstra et al. (2000), investors' way to make decisions could be affected by lowered risk tolerance, caused by time change sleep disruptions. Small changes in sleep schedule and their effect on events affected by decision-making have been studied in contexts such as traffic accidents and work-related accidents.

The connection between seasonal time changes and traffic accidents has been studied in different locations. Monk (1980) finds that traffic accidents increase following a time change in Britain, and Hicks et al. (1983) find a significant increase in traffic accidents following a time change in California, US, both regardless of whether it is spring or fall. Coren (1996) finds that the spring time change causes an increase of 8 percent in traffic accidents, but the fall time change causes a reduction in accidents of the same magnitude in Canada. On the contrary, Lahti et al. (2010) find no relationship between traffic accidents and seasonal time changes in Finland.

Barnes & Wagner (2009) study the effect of seasonal time changes on workplace injuries in the US and find that Mondays following a spring time change lead to not only more injuries, but also more serious injuries. They find that fall time change does not cause a difference in injuries comparing to normal days. The authors state that seasonal time changes cause workers to be in clear and imminent danger. What is more, Mitler et al. (1988) and Coren (1997) discuss how disasters, such as the Chernobyl nuclear accident and the space shuttle Challenger incident, appear to be connected to sleep-related factors. However, Lahti et al. (2011) find no increase in work-related accidents in relation to seasonal time changes in Finland.

As prior research shows contrary results, it is not clear whether minor sleep disturbances are at fault for adverse, decision-driven events, and whether they could be avoided with a consistent sleep schedule. As some evidence for the effect has been discovered in traffic and work-related accidents, it is of interest whether sleep disturbances show in financial markets, since they also depend on people's decision-making ability.

2.3. Time change effect

Kamstra et al. (2000) start a discussion on the topic of seasonal time change effect by investigating the effect of time changes on stock market indices in the US, Canada, the UK and Germany. They find the mean returns of spring time change weekends to be 2 to 5 times the magnitude of regular weekends. The effect is even larger on fall time change weekends. These results are significant for all the studied countries except Germany, where the result becomes significant by deleting one outlier. The authors suggest that the effect might be due to a disruption in sleeping rhythm when a time change occurs. They propose that such a disturbance causes anxiety in investors, which lowers their risk tolerance in the following trading day. This shunning of risks could cause the prices to descend.

Pinegar (2002) further tests the robustness of the findings of Kamstra et al. (2000). He states that the results are only significant for fall time change weekends, which are no longer significant after removing outliers. He also suggests that the results of Kamstra et al. (2000) might be due to the already known Monday anomaly. Kamstra et al. (2002) answer Pinegar in disapproval of his methods and provide further evidence on the possible time change anomaly. They add to Pinegar's cumulative distribution function plots to demonstrate the greater number of negative returns but also the lower number of positive returns on time change weekends compared to regular weekends.

Berument, Dogan and Onar (2010) study time change effects in both stock returns and volatility using US data. They use the Exponential Generalized ARCH model and find no time change effect. Kamstra et al. (2010) highly criticize the methods of Berument et al., stating that their model is overparameterized, prone to biased coefficient estimates and could not be replicated. Kamstra et al. further claim that Berument et al. found significant results by using an OLS estimation and the original sample of Kamstra et al. (2000), but did not report them.

Interestingly, Berument & Dogan (2011) later find that the time change effect exists and holds even after controlling on the outliers pointed out by Pinegar (2002). They examine the connection between time changes, stock returns and volatility by using the same US indices as Kamstra et al. (2000). They also find that the time change effect has more magnitude in more volatile times.

Dowling & Lucey (2005) examine the relationship between investor mood and Irish stock returns. They use the biannual time changes as one of their mood proxies and find a significant effect on time change weekend returns even after controlling for the outliers pointed out by Pinegar (2002). On the contrary, other studies targeting one country and focusing on seasonal time changes only, such as Worthington (2003) with Australian data, Lamb et al. (2004) with US data, Boido & Fasano (2005) with Italian data, and Müller et al. (2009) with German data, do not support the existence of the time change effect.

Dowling & Lucey (2008) also investigate the mood-stock return relationship, but in a global setting using a sample of 40 countries. They do not find a significant connection between returns and time change mood proxy in the majority of the indices they examine. Similarly, Gregory-Allen et al. (2010) who also use global data with a 22-country sample, do not support the time change effect.

The literature on the possible time change effect that causes lower stock returns on the Monday following a time change weekend is limited. Even though the majority of the studies show no time change effect, the debate on the existence of the effect is ongoing. As there is no consensus on the topic, it needs further examination.

The geographical focus in the subject is in the US for most, global market in some, and national in a few studies. Thus, there lacks a study on the European stock market, where the topic is timely due to the European Union's ongoing process on stopping the biannual time changes in 2021. Moreover, the European Economic Area is significant for the world economy, and the continent populates nearly 10% of the world's population, beating for example North America. Kamstra et al. (2000) argue that the time change effect costs daily thousands of millions of dollars in the US. Thus, if the time change effect exists in the European market, the costs of it might be tremendous and grand savings could be expected from 2021 onwards, when time changes are halted. Therefore, I focus on European national stock market indices.

2.4.Monday effect

If a time change effect seems to exist, the coexistence of the Monday effect must be considered: Is the effect caused by the Monday effect or the seasonal time changes? The Monday effect, or weekend effect, is a well-known phenomenon in the financial markets: The stock prices tend to be lower on Mondays compared to the days preceding and across different securities (see e.g. Cross, 1973; French, 1980; Gultekin & Gultekin, 1983; Dubois & Louvet, 1996; Cho, et al., 2007), even in the cryptocurrency market (see e.g. Décourt, et al., 2017; Caporale & Plastun, 2019). Since the seasonal time changes usually occur on Sundays, the following day, Monday, is a subject to this anomaly.

3. Hypotheses

Based on the existing literature, the research question to be investigated is: Do the seasonal time changes between standard time and summer time have an adverse effect on European stock returns?

Authors, such as Kamstra et al. (2000; 2002; 2010), Berument & Dogan (2011), and Dowling & Lucey (2005), find that Mondays following time change weekends have lower returns compared to regular Mondays. Thus, the main hypothesis is the following: *Seasonal time changes (spring and fall together) lead to lower returns on the immediately following Mondays compared to regular Mondays.*

The main hypothesis is based on the argument that time change leads to a disruption in sleeping rhythm, which causes anxiety in investors and lowers their risk tolerance in the following trading day. Followingly, this shunning of risks causes prices to descend. (Kamstra, et al., 2000)

Kamstra et al. (2000) argue based on literature on traveler jet lag that any sleep disturbance, whether sleeping time is lost or gained, causes an adverse effect on response time and problem-solving ability. Thus, my additional hypothesis is the following: *Seasonal time changes (whether it is spring or fall) lead to lower returns on the immediately following Mondays compared to regular Mondays.*

4. Data

The data sample contains 28 European countries, 25 of which are currently members of the European Union: Austria, Belgium, Bulgaria, Croatia, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Lithuania, Luxembourg, Malta, the Netherlands, Norway, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, Switzerland, and the United Kingdom (UK).

For each country, I use daily total returns in home currency of the value-weighted total market index, retrieved from DataStream. The sample period start date varies due to data availability from January 1965 for the UK to March 2006 for Slovakia and ends for all countries in

December 2019. The average sample length is 35 years, the average number of data points is 8 802 and the average number of time change occurrences is 84. A conclusive table on the full data sample can be found in the Appendix.

Time change dates are collected from IANA Time Zone Database, www.TimeAndDate.com by Time and Date AS, and GreenwichMeanTime.com by Greenwich 2000 Limited.

5. Methods and findings

First, I perform analyses on return means which provide a big picture on possible trends and differences between different days in the data. Additional t-tests between different means allows to compare the significance of the possible differences. Second, I perform a multiple regression analysis with several numbers of lags. The multiple regression enables to measure the impact of different factors that could be underlying in the observations, such as the Monday effect. Third, I plot cumulative distribution functions to illustrate the frequency of positive and negative values for time change Mondays and regular Mondays.

5.1.Means

Extending on Kamstra et al.'s (2000) work, I calculate the means of daily total returns for each country for the following days:

- All weekdays
- All weekdays but Mondays
- All Mondays
- Regular Mondays, when no time change occurs
- Mondays with time change, spring and fall together
- Mondays with time change, only spring
- Mondays with time change, only fall

The means are reported in Table 1. "All Mondays" includes every Monday whether a time change occurs or not, and "Regular Mondays" includes Mondays with no time change occurring on the preceding weekend. "Spring and fall" includes all time change Mondays, "Spring" includes only time change Mondays occurring in spring, and "Fall" includes only time change Mondays occurring in fall. The difference between regular Mondays and time change Mondays, and the t-statistic of a two-sample one-sided t-test, are shown on the last two columns.

TABLE 1. MEANS OF DAILY RAW RETURNS DATA

Country	All days	Other days than Mondays	All Mondays	Regular Mondays	Spring and fall	Spring	Fall	Regular Mondays – Spring and fall	t-statistic	
Austria	0.033	0.035	0.023	0.023	0.005	0.047	-0.038	0.019	0.125	
Belgium	0.040	0.047	0.010	0.011	-0.027	0.016	-0.070	0.038	0.336	
Bulgaria	0.058	0.076	-0.016	-0.015	-0.043	0.026	-0.108	0.028	0.155	
Croatia	0.025	0.063	-0.131	-0.115	-0.525	-0.230	-0.800	0.410	1.734	***
Czech Republic	0.042	0.040	0.051	0.058	-0.130	0.003	-0.264	0.188	0.849	
Denmark	0.051	0.048	0.064	0.062	0.810	0.148	0.085	-0.055	-0.433	
Estonia	0.035	0.064	-0.085	-0.069	-0.527	-0.409	-0.639	0.458	2.104	***
Finland	0.049	0.059	0.011	0.016	-0.093	-0.027	-0.159	0.109	0.510	
France	0.049	0.072	-0.040	-0.039	-0.060	0.082	-0.202	0.021	0.144	
Germany	0.036	0.041	0.014	0.011	0.078	0.449	0.092	-0.067	-0.406	
Greece	0.029	0.055	-0.075	-0.069	-0.239	-0.062	-0.417	0.171	0.730	
Hungary	0.061	0.050	0.108	0.121	-0.215	-0.110	-0.316	0.336	1.391	**
Ireland	0.049	0.058	0.013	0.017	-0.086	-0.093	-0.079	0.102	1.069	
Italy	0.045	0.073	-0.064	-0.059	-0.187	-0.235	-0.139	0.128	0.830	
Lithuania	0.028	0.041	-0.028	-0.025	-0.103	0.062	-0.259	0.078	0.635	
Luxembourg	0.036	0.045	-0.001	0.001	-0.049	0.019	-0.117	0.050	0.513	
Malta	0.022	0.008	0.076	0.065	0.349	-0.037	0.734	-0.284	-1.508	
Netherlands	0.044	0.054	0.003	0.010	-0.188	-0.088	-0.288	0.198	1.398	**
Norway	0.053	0.062	0.014	0.022	-0.177	-0.111	-0.243	0.199	1.228	
Poland	0.027	0.012	0.088	0.097	-0.133	-0.122	-0.143	0.229	1.071	
Portugal	0.023	0.029	-0.002	-0.001	-0.015	0.072	-0.103	0.014	0.124	
Romania	0.086	0.106	0.005	0.031	-0.659	-0.531	-0.787	0.690	1.926	***
Slovakia	0.027	0.038	-0.016	-0.019	0.053	0.123	-0.017	-0.072	-0.461	
Slovenia	0.024	0.053	-0.089	-0.082	-0.265	-0.205	-0.325	0.182	0.989	
Spain	0.039	0.048	0.006	0.015	-0.214	-0.066	-0.362	0.229	1.422	**
Sweden	0.060	0.062	0.051	0.057	-0.109	-0.036	-0.182	0.166	0.872	
Switzerland	0.035	0.050	-0.027	-0.026	-0.047	-0.041	-0.053	0.021	0.161	
UK	0.049	0.071	-0.037	-0.028	-0.264	-0.270	-0.257	0.235	1.933	***

The table shows the means of daily raw total returns in percentage for total market indices. "All Mondays" refers to every Monday whether a time change occurs or not, "Regular Mondays" refers to Mondays with no time change occurring on the preceding weekend, "Spring and fall" refers to all time change Mondays, "Spring" refers to time change Mondays occurring in spring, and "Fall" refers to time change Mondays occurring in fall. The difference between regular Mondays and time change Mondays, and t-statistic of a two-sample, one-sided t-test are shown on the last two columns. Time span start date varies due to data availability from January 1965 for the UK to March 2006 for Slovakia and ends for all countries in December 2019. Data is retrieved from DataStream. Levels of significance: * at 10%, ** at 5%, *** at 1%.

According to the main hypothesis, we should see that time change Monday mean returns are significantly lower than regular Monday mean returns. However, a significant difference between time change Mondays (spring and fall together) and regular Mondays is found in only 7 out of 28 countries: Croatia, Estonia, Hungary, the Netherlands, Romania, Spain, and the UK. Nevertheless, 24 out of 28 countries have lower returns on time change Mondays compared to regular Mondays. Most (24 out of 28) of the time change Monday mean returns are negative, whereas regular Monday mean returns are mostly positive (16 out of 28).

These results suggest that there is no time change effect on stock market returns in most of the European markets and do not support the main hypothesis in them. The main hypothesis cannot, however, be rejected in Croatia, Estonia, Romania, and the UK, where the effect shows at 1% significance level, and in Hungary, the Netherlands and Spain, where the effect shows at 5% significance level.

According to the additional hypothesis, we should see that time change Monday mean returns, for spring and fall separately, are significantly lower than regular Monday mean returns. However, additional t-tests on differences between spring time change and fall time change returns, spring time change and regular Monday returns, and fall time change and regular Monday returns do not show significant results for virtually any country. Thus, the results do not support the additional hypothesis. Nevertheless, similarly to the findings of Kamstra et al. (2000), fall time change returns are lower than spring time change returns in 24 out of 28 countries, but most of these results are not statistically significant.

5.2.Multiple regressions

Adapting the regression formula by Kamstra et al. (2010), I will use the following multiple regression with 0, 5 and 10 lags inspired by Kamstra et al. (2010), and Berument and Dogan (2010).

$$R_t = \alpha_0 + \alpha_{Mon} Mon_t + \alpha_{Change} Change_t + \alpha_{Jan} Jan_t + \alpha_i \sum_{i=1}^{n} R_{t-i} + \varepsilon_t, \qquad [1]$$

where

- R_t is the index return.
- Dummy variables:
  - Mon_t is set to 1 on Monday, set to 0 otherwise.
  - $Change_t$ is set to 1 on Monday immediately following a time change weekend, set to 0 otherwise. Following Dowling and Lucey (2005), I do not use Tuesday returns when the market is closed on Monday, because the time change effect's influence on investor mood is not likely last until Tuesday.
  - Jan_t is set to 1 if the trading day is in January, set to 0 otherwise.
- ε_t is a residual.
- α terms are parameters of the model:
  - α_0 is an intercept term.
  - α_{Mon} is the Monday dummy variable coefficient estimate.
  - α_{Change} is the time change coefficient estimate.
  - α_{Jan} is the January variable.
  - α_i (for $i = 1 \dots n$) are the coefficient estimates on the n lags of the dependent variable.

I use the January dummy variable instead of using a variable for the first month of the tax year like Kamstra et al. (2010). The sample consists of multiple countries with long time periods and varying tax policies, all of which except for the UK currently start their fiscal year in the beginning of the calendar year. The rationale in using the January dummy variable also lies in the existence of the January effect, anomaly in which especially small cap stocks have abnormally large returns in January (see e.g. Thaler, 1987; Haugen & Jorion, 1996; Haug & Hirschey, 2006). Thus, I expect to see positive January coefficients. No time changes occur in January in the data.

Kamstra et al. (2010) argue against the number of lags, 15, chosen by Berument and Dogan (2010). Kamstra et al. (2010) express how exceptional it is to use up to 15 lags in return regressions, and remind that including even one lag goes against market efficiency. They state that using lags might still be needed in the context of index returns, for the reason of nonsynchronous trading of individual stocks in the index. Still, the authors state that using as many as 15 lags to detect autocorrelations is likely to be spurious. Thus, I use 0, 5 and 10 lags to examine differences among the results. The results for the regression with no lags are shown in Table 2.

According to the main hypothesis, we should see negative and significant time change coefficient estimates. However, as the estimated time change coefficients are negative for most of the countries (23–24 out of 28), they are both negative *and* significant in at least 10% level for only 4 or 5 countries depending on the number of lags. Thus, like in the mean returns, we can see the time change effect only in a minority of the countries. Depending on the number of lags, these countries include Croatia, Estonia, Hungary, the Netherlands, Romania, and the UK. My results suggest that there is no time change effect in most of the European countries and, like in the examination of the mean returns, do not support the main hypothesis in them. The main hypothesis cannot, however, be rejected in Croatia, Estonia, Hungary, the Netherlands, Romania, and the UK, where a time change effect seems to exist at least on 10% significance level.

The estimated Monday dummy coefficients are negative for most of the countries (23 out of 28). They are both negative and significant with at least 10% level for 11–13 out of 28 countries depending on the number of lags. Thus, the Monday effect can be seen in these countries.

The estimated January coefficients are positive for most of the countries (26 out of 28), as expected. They are both positive and significant in at least 10% level for 12–16 countries depending on the number of lags. Thus, the January effect can be seen in these countries.

TABLE 2. MULTIPLE REGRESSION WITH NO LAGS

	Intercept		Monday		Change		January		Multiple R^2	Adjusted R^2
Austria	0.032	***	-0.012		-0.016		0.035		0.000141	-0.000104
Belgium	0.041	***	-0.037	*	-0.031		0.069	**	0.000677	0.000432
Bulgaria	0.082	***	-0.091		-0.034		-0.067		0.000718	0.000121
Croatia	0.053	***	-0.179	***	-0.399	**	0.121	**	0.008700	0.007899
Czech Republic	0.029		0.018		-0.176		0.131	**	0.000977	0.000538
Denmark	0.038	***	0.014		0.065		0.121	***	0.001060	0.000815
Estonia	0.044	**	-0.134	***	-0.437	*	0.251	***	0.004503	0.003995
Finland	0.052	**	-0.044		-0.101		0.087		0.000388	0.000026
France	0.066	***	-0.111	***	-0.015		0.067	*	0.001756	0.001512
Germany	0.039	***	-0.030		0.069		0.021		0.000169	-0.000076
Greece	0.046	*	-0.124	**	-0.160		0.116		0.001175	0.000792
Hungary	0.034	*	0.071		-0.320		0.190	***	0.001833	0.001430
Ireland	0.048	***	-0.042		-0.091		0.126	***	0.001220	0.000976
Italy	0.059	***	-0.133	***	-0.113		0.163	***	0.002924	0.002680
Lithuania	0.028	*	-0.067	**	-0.065		0.158	***	0.002873	0.002345
Luxembourg	0.042	***	-0.044		-0.047		0.033		0.000448	0.000037
Malta	-0.001		0.056	**	0.293	**	0.107	***	0.004157	0.003583
Netherlands	0.048	***	-0.044	*	-0.193		0.063	*	0.000861	0.000616
Norway	0.057	***	-0.040		-0.193		0.066		0.000516	0.000228
Poland	0.002		0.085	*	-0.219		0.124	*	0.001008	0.000563
Portugal	0.021		-0.030		-0.006		0.087	**	0.000708	0.000325
Romania	0.092	***	-0.075		-0.676	**	0.170	*	0.001863	0.001365
Slovakia	0.040	**	-0.057		0.070		-0.026		0.000764	-0.000068
Slovenia	0.043	***	-0.136	***	-0.172		0.115	***	0.006006	0.005461
Spain	0.043	***	-0.033		-0.224		0.054		0.000598	0.000247
Sweden	0.056	***	-0.005		-0.160		0.074		0.000364	0.000061
Switzerland	0.047	***	-0.076	***	-0.018		0.037		0.001249	0.001005
UK	0.065	***	-0.100	***	-0.216	**	0.067	**	0.002485	0.002277

Coefficient estimates of multiple regression [1] with zero lags. Monday is a dummy variable set to one on a Monday and zero otherwise, Change is a dummy variable set to one on a Monday immediately following a time change weekend, zero otherwise, and January is a dummy variable set to one in January, zero otherwise. Time span start date varies due to data availability from January 1965 for the UK to March 2006 for Slovakia and ends for all countries in December 2019. Data is retrieved from DataStream. Levels of significance: * at 10%, ** at 5%, *** at 1%.

5.3. Cumulative distribution functions

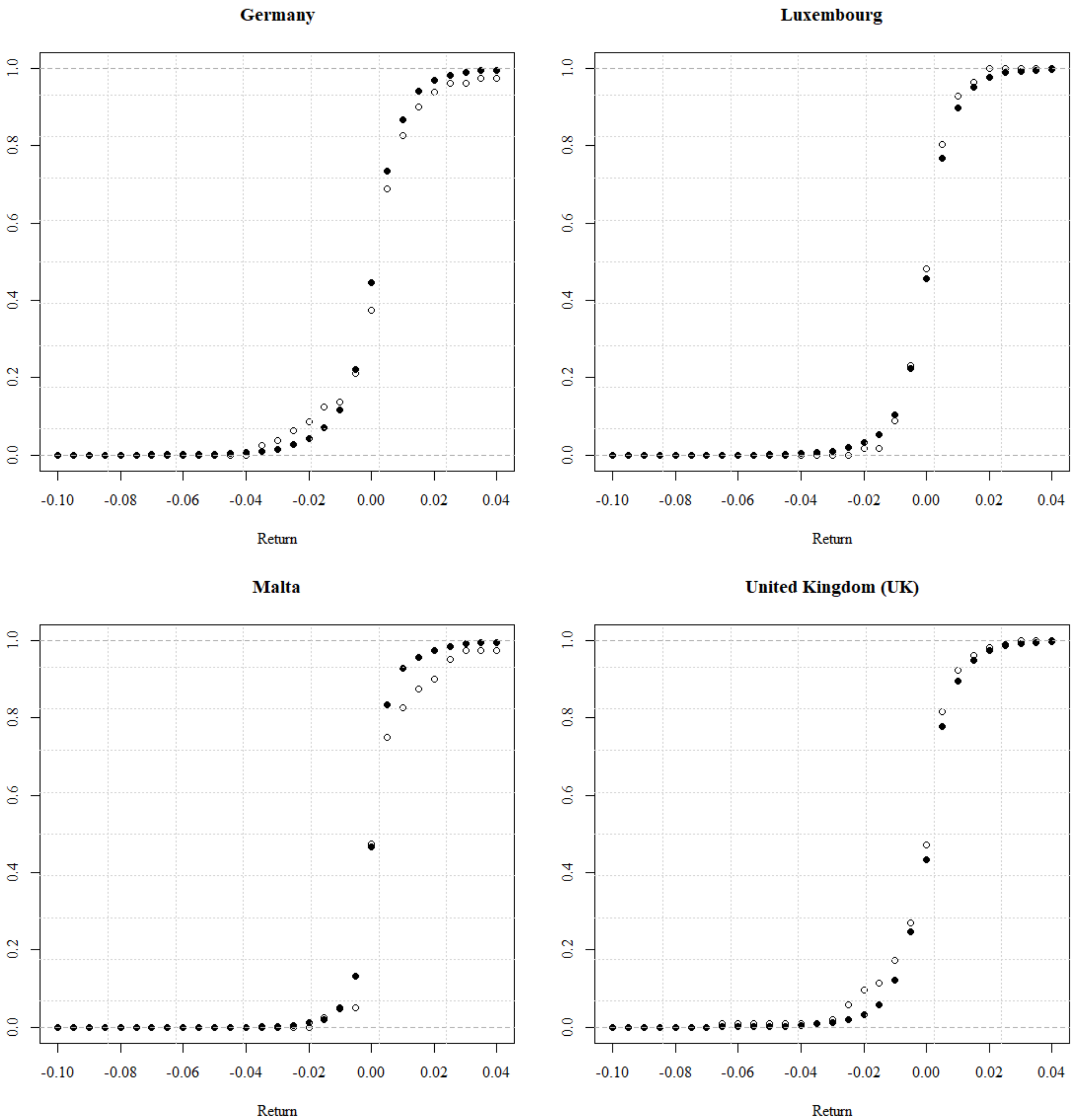
Following Pinegar (2002) and Kamstra et al. (2002), I plot cumulative distribution functions (c.d.f.'s) for each country's regular Monday returns and time change Monday returns (spring and fall together) to examine the distribution of positive and negative returns. The plots for Germany, Luxembourg, Malta, and the UK, are presented in Figure 1. These countries represent different types of c.d.f.'s in the data. In each plot, the solid dots are for regular Monday returns without time change Mondays, and hollow dots are for time change Mondays.

The lower tails of the plots show that most of the countries (20 out of 28) have a greater frequency of negative returns on time change Mondays compared to regular Mondays. For example, c.d.f. plots of Germany and the UK show clearly that the lower tail has more negative returns on time change Mondays compared to regular Mondays. 8 countries do not show this effect, including Luxembourg and Malta.

Contrary to Kamstra et al. (2002), most of the higher tails (20 out of 28) have a greater frequency of positive returns on time change Mondays, not regular Mondays. For example, Luxembourg and the UK show this effect. 8 countries including Germany and Malta, however, show a lack of positive returns on time change Mondays in the higher tail of the c.d.f.

Only 6 out of 28 countries (Austria, Denmark, France, Germany, Sweden and Switzerland) behave likewise to Kamstra et al. (2002), and show both a greater frequency of negative returns and a lower frequency of positive returns on time change Mondays. Half of the countries (14 out of 28) have a greater frequency of negative returns, but also a greater frequency of positive returns on time change Mondays, including the UK. 6 out of 28 countries, including Luxembourg, show opposite results to Kamstra et al. (2002). The c.d.f. plots fail to show signs of the time change effect for the majority of the countries. However, interpreting the plots is somewhat subjective, and thus is used here for only illustrating and comparing the findings to existing literature.

FIGURE 1. CUMULATIVE DISTRIBUTION FUNCTIONS FOR REGULAR MONDAYS AND TIME CHANGE MONDAYS (SPRING AND FALL)



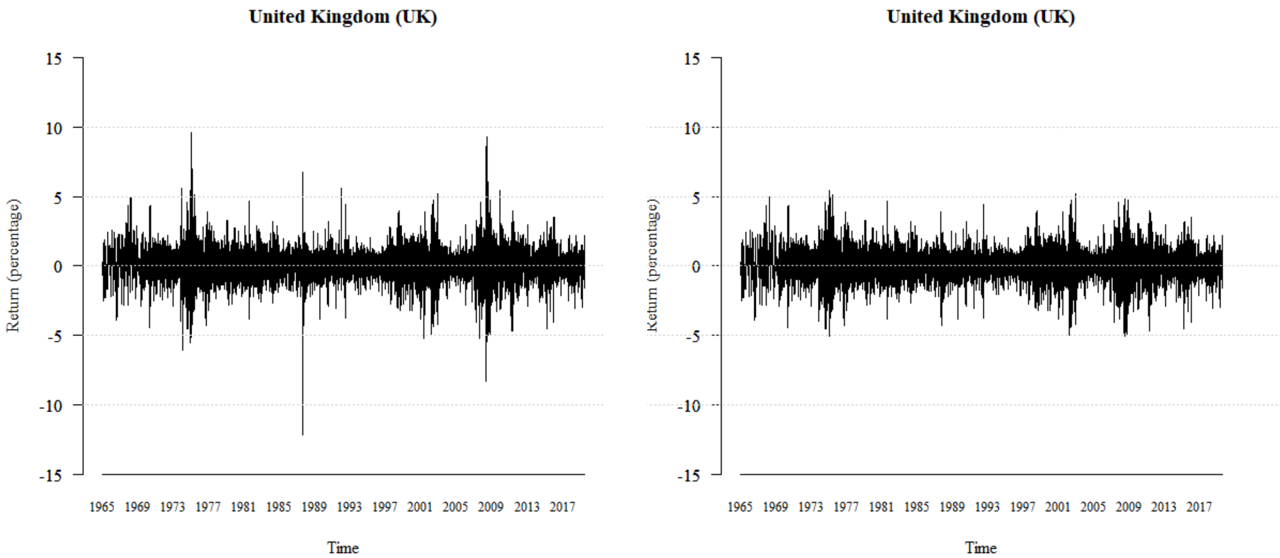
○○○ Time change Mondays (spring and fall) ●●● Regular Mondays (no time change Mondays included)
Time span start date varies due to data availability from January 1965 for the UK to January 2000 for Malta and ends for all countries in December 2019. Data is retrieved from DataStream.

6. Robustness checks

6.1. Removing outliers

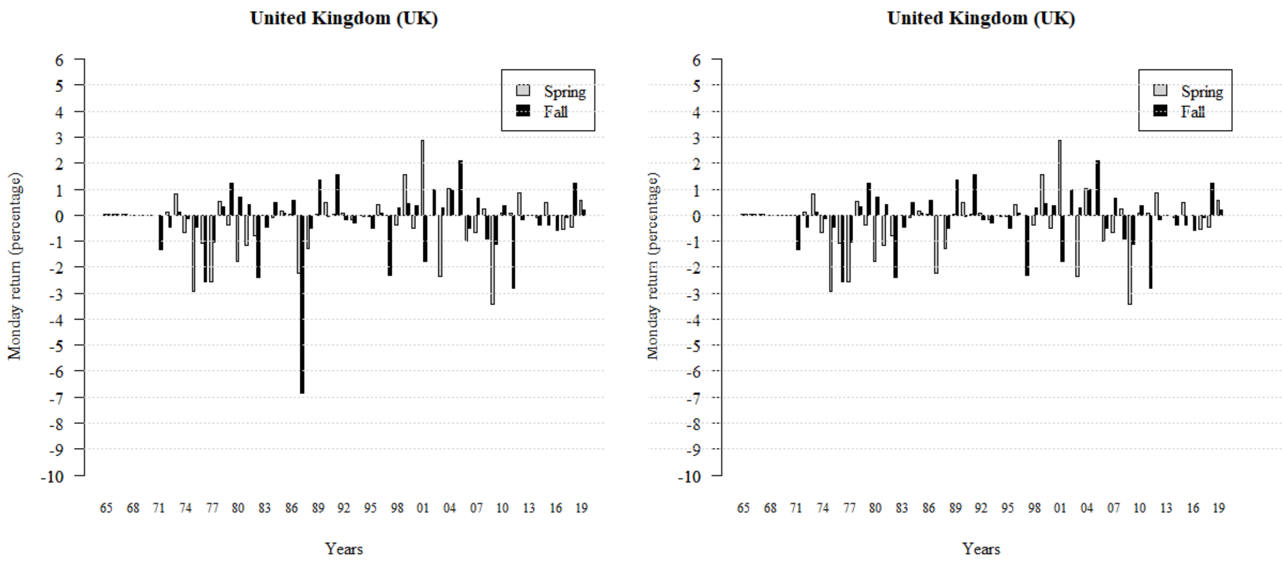
As Pinegar (2002) points out, the results could be affected by outliers in the data. The outliers could be caused by for instance significant economic events or news. Taking the largest and smallest observations into account can yield biased results. As the first robustness check, I remove the smallest and largest 0.1% of the financial data points. For an illustrative example, Figure 2 shows the dataset before and after outlier removal for the UK for the full dataset and Figure 3 for time change data.

FIGURE 2. FULL DATASET FOR THE UK BEFORE AND AFTER OUTLIER REMOVAL



On the left: The full dataset for the UK. On the right: The dataset after 0.1% of the smallest and largest observations are removed. Time period: January 1, 1965, to December 31, 2019.

FIGURE 3. TIME CHANGE DATASET FOR THE UK BEFORE AND AFTER OUTLIER REMOVAL



On the left: The full time change Monday dataset for the UK. On the right: The time change Monday dataset after 0.1% of the smallest and largest observations are removed. We can see how only the negative observation of the fall 1987 is removed. Time period: January 1, 1965, to December 31, 2019.

The results of the regression [1] with no outliers and no lags are presented in Table 3. Removing outliers does not make a significant difference for most of the countries. The estimated time change coefficients are statistically significant in an even smaller number of countries than with outliers, but the difference is not notable. For a few countries, the coefficient is positive with outliers excluded, while it is negative with outliers. The estimated Monday coefficients are slightly more significant for lagged regressions without outliers. The estimated January coefficients are slightly less significant without outliers, but the difference is not large.

The return means for all Mondays are smaller with outliers than without them for 16 countries. Regular Monday returns are smaller with outliers for 14 countries out of 28 than without them. However, time change Monday returns with outliers are smaller than returns without outliers for only 5 countries. Significance of the various t-tests does not change virtually for any country when outliers are excluded. The results of deleting outliers suggest that they do not affect the results of mean analysis for most countries.

Removing the smallest and largest 0.1% of observations supports the results reported in the previous section Methods and findings.

TABLE 3. MULTIPLE REGRESSION WITH NO LAGS AFTER OUTLIER REMOVAL

	Intercept		Monday		Change		January		Multiple R^2	Adjusted R^2
Austria	0.033	***	-0.008		0.078		0.014		0.000073	-0.000172
Belgium	0.041	***	-0.028		-0.039		0.058	**	0.000508	0.000263
Bulgaria	0.092	***	-0.138	***	0.004		-0.042		0.001881	0.001283
Croatia	0.054	***	-0.197	***	-0.381	**	0.124	**	0.012051	0.011251
Czech Republic	0.028	*	0.026		-0.034		0.056		0.000262	-0.000179
Denmark	0.039	***	0.011		0.066		0.095	***	0.000849	0.000604
Estonia	0.045	**	-0.122	***	-0.450	**	0.208	***	0.004073	0.003564
Finland	0.055	***	-0.045		-0.103		0.056		0.000301	-0.000062
France	0.067	***	-0.116	***	-0.011		0.068	*	0.002056	0.001811
Germany	0.038	***	-0.018		-0.005		0.016		0.000072	-0.000173
Greece	0.044	*	-0.128	**	-0.155		0.140	**	0.001509	0.001126
Hungary	0.038	**	0.061		-0.314	*	0.171	***	0.001725	0.001321
Ireland	0.050	***	-0.041		-0.095		0.109	***	0.001109	0.000864
Italy	0.061	***	-0.142	***	-0.105		0.164	***	0.003430	0.003185
Lithuania	0.028	**	-0.064	**	-0.067		0.158	***	0.003323	0.002795
Luxembourg	0.043	***	-0.049	*	-0.043		0.023		0.000524	0.000113
Malta	0.005		0.033		0.178		0.095	***	0.002446	0.001870
Netherlands	0.046	***	-0.036		-0.198	*	0.070	**	0.000923	0.000678
Norway	0.055	***	-0.029		-0.203		0.065		0.000507	0.000219
Poland	0.002		0.088	*	-0.222		0.108		0.001015	0.000569
Portugal	0.018		-0.017		-0.016		0.086	**	0.000680	0.000296
Romania	0.081	***	-0.066		-0.445	*	0.178	**	0.001728	0.001228
Slovakia	0.034	**	-0.017		0.036		-0.028		0.000189	-0.000644
Slovenia	0.042	***	-0.131	***	-0.030		0.104	***	0.005504	0.004958
Spain	0.045	***	-0.049		-0.210		0.065		0.000878	0.000527
Sweden	0.057	***	-0.010		-0.156		0.056		0.000288	-0.000016
Switzerland	0.046	***	-0.067	***	-0.026		0.044		0.001190	0.000945
UK	0.065	***	-0.101	***	-0.153		0.062	**	0.002462	0.002253

Coefficient estimates of return equation [1] with zero lags, largest and smallest 0.1 % observations removed. Monday is a dummy variable set to one on a Monday and zero otherwise, Change is a dummy variable set to one on a Monday immediately following a time change weekend, zero otherwise, and January is a dummy variable set to one in January, zero otherwise. Time span start date varies due to data availability from January 1965 for the UK to March 2006 for Slovakia and ends for all countries in December 2019. Data is retrieved from DataStream. Levels of significance: * at 10%, ** at 5%, *** at 1%.

6.2. GARCH process

I estimate GARCH coefficients based on Kamstra et al. (2000) and Kamstra et al. (2010) in order to consider heteroskedasticity, volatility and volatility clustering. The Generalized Autoregressive Conditional Heteroskedasticity model, GARCH model for short, was introduced by Bollerslev (1986), based on the ARCH model of Engle (1982). The model is widely used in financial time series modeling. It is useful for it models the attitude of investors on expected returns, but also risk in uncertainty (Asteriou & Hall, 2016): Kamstra et al. (2000) speculate that the time change effect could be due to sleep disturbance rising investor anxiety and thus, lowering their risk tolerance. The GARCH(1,1) model with an AR(1) model for the mean following Kamstra et al. (2010) is as follows:

$$R_t = \alpha_0 + \alpha_{Mon} Mon_t + \alpha_{Change} Change_t + \alpha_{Jan} Jan_t + \alpha_{AR} R_{t-1} + \varepsilon_t, \qquad [2]$$

with $\varepsilon_t \sim N(0, \sigma^2{}_t)$ and the conditional variance of the error term ε_t modeled as $\sigma^2{}_t = \beta_0 + \beta_1 \varepsilon^2{}_{t-1} + \beta_2 \sigma^2{}_{t-1} + \beta_{Mon} Mon_t + \beta_{Change} Change_t$.

In Equation [2],

- R_t is the index return.
- Dummy variables:
  - Mon_t is set to 1 on Monday, set to 0 otherwise.
  - $Change_t$ is set to 1 on Monday immediately following a time change weekend, set to 0 otherwise. Following Dowling and Lucey (2005), I do not use Tuesday returns when the market is closed on Monday, because the time change effect's influence on investor mood is not likely last until Tuesday.
  - Jan_t is set to 1 if the trading day is in January, set to 0 otherwise.
- α terms are parameters of the **mean model**:
  - α_0 is an intercept term.
  - α_{Mon} is the Monday dummy variable coefficient estimate.
  - α_{Change} is the time change coefficient estimate.
  - α_{Jan} is the January variable.
  - α_{AR} is the coefficient estimate on the autoregression of the dependent variable.
- ε_t is the error term.
- $\sigma^2{}_t$ is the conditional variance of the error term.

- β terms are parameters of the **variance model**:
  - β_0 is an intercept term.
  - β_1 is the ARCH term.
  - β_2 is the GARCH term.
  - β_{Mon} is the Monday dummy variable coefficient estimate.
  - β_{Change} is the time change coefficient estimate.

The coefficient estimates for the GARCH model are presented in Table 4. The results are very similar with different numbers of lags and thus, are not discussed here for the sake of brevity.

The estimated mean model coefficients largely reflect the results of the multiple regression. I find a notable difference only in the time change coefficient estimates. The estimated time change coefficients of the GARCH model are negative for only 9 countries out of 28 (Croatia, the Czech Republic, Estonia, Finland, Ireland, Lithuania, the Netherlands, Spain, and the UK), significantly so for none. In fact, the only significant time change coefficient is Austria's positive one at 1% level. The GARCH estimation does not show signs of time change effect even for the small number of countries that show it in the multiple regression. My results suggest that there is no time change effect in the European countries and like in means and multiple regression analysis, do not support the main hypothesis.

The estimated Monday coefficients are in line with the multiple regression results for that 21 of 28 coefficient estimates are negative. The estimates are both negative and significant, all at 1%, level for 11 countries out of 28 similarly to multiple regression estimates.

The estimated January coefficients are also in line with multiple regression results: 25 out of 28 coefficient estimates are positive, 18 of them significantly so at least at 5% level, whereas in multiple regression the number is 16.

TABLE 4. GARCH ESTIMATION

	Return specification										Variance specification									
	Intercept		AR term		Monday		Change		January		Intercept		ARCH term		GARCH term		Monday		Change	
Austria	0.032	***	0.132	***	-0.016		0.108	***	-0.017		0.002		0.045	***	0.954	***	1.00E-08		9.98E-09	
Belgium	0.053	***	0.119	***	-0.014		0.063		0.079	***	0.017	**	0.107	***	0.876	***	1.12E-08		9.51E-09	
Bulgaria	0.038	***	0.039	**	-0.068	***	0.068		0.057		0.001		0.048	***	0.958	***	1.00E-08		1.00E-08	
Croatia	0.045	***	-0.041		-0.181	***	-0.071		0.109	**	0.018		0.144	**	0.849	***	1.18E-08		9.83E-09	
Czech Republic	0.053	***	0.065	***	0.019		-0.006		0.064		0.017		0.094	***	0.897	***	1.00E-08		1.00E-08	
Denmark	0.217		0.082		0.166		0.114		-1.106		0.001		0.058		0.923		1.00E-08		1.00E-08	
Estonia	0.044	***	0.005		-0.083	***	-0.190		0.136	***	0.006		0.102	***	0.905	***	1.00E-08		1.00E-08	
Finland	0.067	***	0.091	***	-0.041		-0.022		0.115	***	0.011		0.067	***	0.930	***	9.99E-09		1.00E-08	
France	0.095	***	0.096	***	-0.104	***	0.071		0.072	***	0.032	***	0.107	***	0.869	***	1.02E-08		9.63E-09	
Germany	0.055	***	0.081	***	-0.027		0.017		0.065	***	0.016		0.094	***	0.892	***	1.09E-08		9.96E-09	
Greece	0.074	***	0.112	***	-0.119	***	0.070		0.153	***	0.012		0.066	***	0.933	***	1.01E-08		1.00E-08	
Hungary	0.052	***	0.075	***	0.037		0.060		0.082		0.050	**	0.110	***	0.869	***	1.02E-08		1.03E-08	
Ireland	0.064	***	0.132	***	-0.061	***	-0.024		0.113	***	0.040	***	0.105	***	0.865	***	1.31E-07		3.44E-08	
Italy	0.075	***	0.079	***	-0.105	***	0.068		0.141	***	0.030	**	0.084	***	0.900	***	1.02E-08		9.99E-09	
Lithuania	0.042	***	0.068	***	-0.055	***	0.000		0.166	***	0.003		0.073	***	0.932	***	1.00E-08		9.99E-09	
Luxembourg	0.059	***	-0.067	***	-0.022		0.041		0.008		0.048	***	0.144	***	0.814	***	7.94E-10		9.09E-09	
Malta	0.002		0.090	***	0.025		0.127		0.019		0.033	***	0.201	***	0.692	***	1.04E-01	***	8.55E-01	**
Netherlands	0.068	***	0.068	***	0.068		0.068		0.068	***	0.068	***	0.068	***	0.068	***	6.81E-02		6.81E-02	
Norway	0.081	***	0.063	***	0.003		0.063		0.069		0.053	***	0.128	***	0.848	***	1.20E-08		1.06E-08	
Poland	0.031	**	0.095	***	0.062	**	0.137		0.096		0.015		0.067	***	0.926	***	1.00E-08		1.00E-08	
Portugal	0.050	***	0.111	***	-0.016		0.109		0.131	***	0.011		0.108	***	0.886	***	2.65E-08		7.94E-09	
Romania	0.090	***	0.080	***	-0.027		0.052		0.263	***	0.035		0.189	***	0.832	***	1.31E-08		9.37E-09	
Slovakia	0.049	***	-0.156	***	-0.024		0.140		-0.032		0.006		0.024	***	0.970	***	1.00E-08		1.01E-08	
Slovenia	0.051	***	0.123	***	-0.121	***	0.074		0.102	***	0.023		0.116	***	0.849	***	2.32E-08		6.16E-09	
Spain	0.070	***	0.081	***	-0.019		-0.025		0.093	***	0.026		0.097	***	0.886	***	1.47E-08		9.34E-09	
Sweden	0.092	***	0.069	***	-0.012		0.037		0.083	***	0.026		0.088	***	0.898	***	1.34E-08		1.00E-08	
Switzerland	0.072	***	0.103	***	-0.051	***	0.031		0.062	**	0.017		0.121	***	0.864	***	1.06E-08		9.94E-09	
UK	0.076	***	0.075	***	-0.082	***	-0.022		0.047	**	0.016		0.069	***	0.912	***	1.04E-08		9.34E-09	

Coefficient estimates of GARCH(1,1) model with an AR(1) model for the mean with zero lags. Monday is a dummy variable set to one on a Monday and zero otherwise, Change is a dummy variable set to one on a Monday immediately following a time change weekend, zero otherwise, and January is a dummy variable set to one in January, zero otherwise. Time span start date varies due to data availability from January 1965 for the UK to March 2006 for Slovakia and ends for all countries in December 2019. Data is retrieved from DataStream. Levels of significance: * at 10%, ** at 5%, *** at 1%

As for the variance model, we see that the ARCH and GARCH terms are significant for 27 out of 28 countries – at 1% level for 26 and 5% level for one. Thus, the volatility clearly depends on past errors and past volatility.

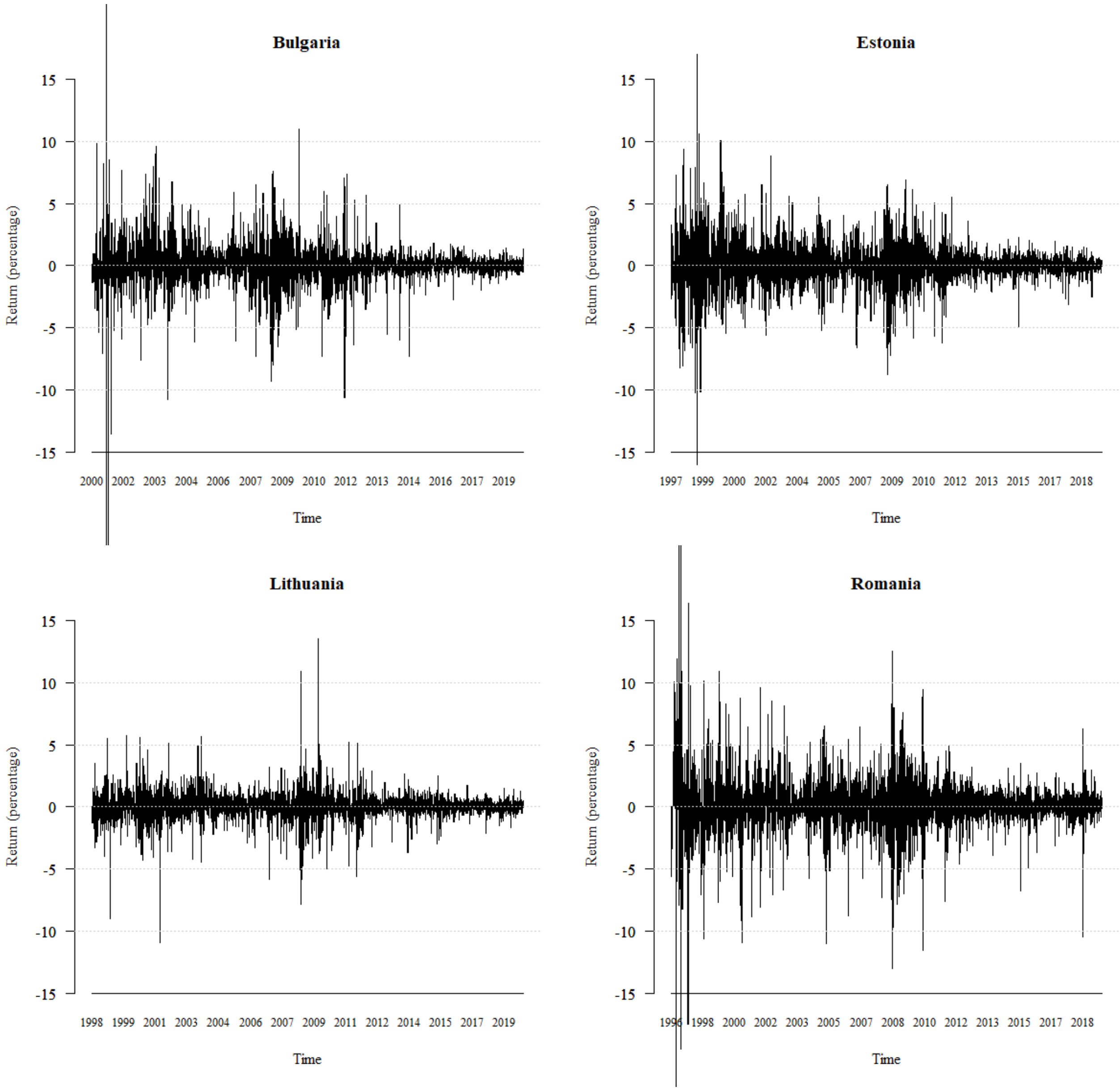
It should be noted that the sum of ARCH and GARCH terms is greater than one for Bulgaria, Estonia, Lithuania, and Romania. Therefore, they do not conform to the stationarity condition. The effect persists after removing outliers for all but Lithuania. We can observe a diminishing trend in volatility in Figure 4, which shows the full return series for the countries with unstationary variance: The volatility is greater in the beginning of these series and diminishes as time goes on. The changing volatility in these countries could stem from uncertainties in the beginning of the time series, such as structural weaknesses remaining from the communist era.

On the contrary, the Monday and time change coefficient estimates are very small in magnitude, and significant for only one country. Hence, the time varying volatility is not much affected by Mondays or time changes.

Some shortcomings of the GARCH model include that it is more parametrized than the multiple regression and can produce biased coefficient estimates in finite samples. It also considers only the magnitude of the volatility, but not its direction. Volatility asymmetry and leverage effect are therefore not considered in GARCH, even though investor behavior is different in increasing markets where the volatility is lower compared to decreasing markets where the volatility is higher (see e.g. Black, 1976; Christie, 1982).

The GARCH model does not support the main hypothesis in any country, and it does not imply that the time varying volatility would be affected by Mondays or time changes. Thus, the GARCH model further supports the findings reported in the previous section Methods and findings.

FIGURE 4. TIME CHANGE DATASETS FOR COUNTRIES NOT CONFORMING TO THE STATIONARITY CONDITION



The full datasets for the countries that do not conform to the stationarity condition as the sums of ARCH and GARCH term are not less than one. These countries are Bulgaria, Estonia, Lithuania, and Romania. For all of them, we can see a diminishing trend in volatility over time. Lithuania's trend is not as clear as the other countries', and after removing outliers it conforms to the condition and the volatility trend disappears.

7. Discussion

My results for the mean analysis, multiple regression analysis, and interpreting c.d.f. plots all fail to support the main hypothesis for most of the European countries. Countries, such as Croatia, Estonia, Hungary, the Netherlands, Romania, and the UK, show an effect to differing extents, but the results do not endure the robustness tests. Thus, the time change effect does not seem to exist in the European stock markets.

My results are in line with for example Boido & Fasano who use Italian data (2005), Dowling & Lucey who use global data (2008), and Müller et al. who use German data (2009), as well as Gregory-Allen et al. who use global data (2010). As there is debate over the phenomenon’s existence, the results are opposite to studies, such as Dowling & Lucey’s (2005) who use Irish data, and those of Kamstra et al.’s who use US data (2000; 2002; 2010): No time change effect could be shown for most of the countries.

A limitation of my study is that it does not exclude the Monday effect, as the time change effect would show on Mondays also. Excluding the Monday anomaly is challenging, since the two effects are difficult to separate, and the time change effect is unlikely to persist in the following Tuesday (Dowling & Lucey, 2005).

Another limitation is that I use value-weighted total market indices. Therefore, the possible differences in company sizes are not visible. A future research idea would be to investigate the possible time change effect in small companies in comparison to larger ones: For example, Kamstra et al. (2000) find the time change effect to be more pronounced in equally weighted indices, where smaller capitalization firms have relatively larger share. Hence, it cannot be excluded that the time change effect might exist only in smaller European companies. My study is also limited for it does not compare different subsets in time: It is possible that the time change effect could be changing over time.

Lamb et al. (2004) suggest that if the negative time change Monday returns are explained by the sleep disruption hypothesis of Kamstra et al. (2000), similar effect could be expected after other events causing sleep disturbances. Lamb et al. (2004) use the original sample of Kamstra et al. (2000) and go on to examine 4th of July (Independence Day of the US) and 17th of March (St Patrick’s Day) and find no significant differences comparing to other days. Furthermore, Pinegar (2002) makes a note that changes in sleeping patterns in weekends overall occur much more often and are likely to be of greater magnitude than the changes in sleeping patterns due to time changes. He attributes the phenomenon to be more of the "day-of-the-week" effect. My results show the Monday anomaly in roughly half of the studied countries. Due to the time change effect being quite incremental if not nonexistent for the European countries, Pinegar's point is well taken.

As the results do not show signs of a time change effect for most of the countries, the stop of the seasonal time changes in the European Union is unlikely to influence the European stock market. However, as some of the Union's largest trading partners, such as Russia and China, do not utilize seasonal time changes, stopping the time changes might be economically beneficial. That is for future to show.

8. Conclusion

In this thesis, I analyze the relationship between the seasonal time changes and European stock returns. I examine if the seasonal time changes between standard time and summer time have an adverse effect on European stock returns. I analyze total market index returns for 28 countries with differing time spans, starting date ranging from January 1965 to March 2006 and ending in 31st December 2019 for all the countries. As my main methods I utilize mean and multiple regression analysis, and I test the robustness of my results by removing outliers and following a standard GARCH process.

The main result of this thesis concludes that there exists no time change effect in the European countries. Countries such as Croatia, Estonia, Hungary, the Netherlands, Romania, and the UK, show the effect to some extent but the result is not robust. However, due to the limitations of my research, it cannot be ruled out that the effect's existence would depend on for example the size of the company. For the future, research on company size or the time span affecting the time change effect would bring more light to the subject.

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Appendix

APPENDIX: METADATA

Country	Current EU member	Start date	End date	Years	Data points	Time changes
Austria	✓	01/01/1973	31/12/2019	47	12 261	80
Belgium	✓	01/01/1973	31/12/2019	47	12 261	86
Bulgaria	✓	03/10/2000	31/12/2019	19	5 021	82
Croatia	✓	03/10/2005	31/12/2019	14	3 716	74
Czech Republic	✓	09/11/1993	31/12/2019	26	6 820	82
Denmark	✓	02/01/1973	31/12/2019	47	12 260	80
Estonia	✓	05/06/1997	31/12/2019	23	5 888	74
Finland	✓	25/03/1988	31/12/2019	32	8 287	78
France	✓	01/01/1973	31/12/2019	47	12 261	88
Germany	✓	01/01/1973	31/12/2019	47	12 261	80
Greece	✓	01/01/1990	31/12/2019	30	7 826	90
Hungary	✓	21/06/1991	31/12/2019	29	7 442	80
Ireland	✓	01/01/1973	31/12/2019	47	12 261	96
Italy	✓	01/01/1973	31/12/2019	47	12 261	100
Lithuania	✓	01/04/1998	31/12/2019	22	5 674	72
Luxembourg	✓	02/01/1992	31/12/2019	28	7 303	86
Malta	✓	04/01/2000	31/12/2019	20	5 215	100
Netherlands	✓	01/01/1973	31/12/2019	47	12 261	86
Norway		02/01/1980	31/12/2019	40	10 434	80
Poland	✓	01/03/1994	31/12/2019	26	6 740	86
Portugal	✓	02/01/1990	31/12/2019	30	7 825	86
Romania	✓	06/12/1996	31/12/2019	23	6 017	82
Slovakia	✓	01/03/2006	31/12/2019	14	3 609	82
Slovenia	✓	31/12/1998	31/12/2019	21	5 478	74
Spain	✓	02/03/1987	31/12/2019	33	8 566	92
Sweden	✓	04/01/1982	31/12/2019	38	9 911	80
Switzerland		01/01/1973	31/12/2019	47	12 261	78
UK		01/01/1965	31/12/2019	55	14 347	107